HOW THE BRITISH ADMIRALTY CHARTS ARE PRODUCED

British Admiralty Charts

PUBLISHED BY THE

HYDROGRAPHIC DEPARTMENT.

The following Article—

"THE PRODUCTION OF AN ADMIRALTY CHART"

has been re-printed, and is presented in this form for the convenience of Officers of the British and Foreign Mercantile Marine Services, and Yachtsmen; by whom it is hoped it may be read with interest.

THE ADMIRALTY CHART AGENCY,
145, MINORIES, LONDON, E. 1.
(J. D. POTTER, AGENT.)

1927.

[*Gratis*]

Reprinted (by permission) from the
"Nautical Magazine," Glasgow, 1927.

The Production of an Admiralty Chart.

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IN the following pages an attempt is made to describe the principles underlying the construction of an Admiralty Chart, the sources of the data used and the main stages in the production of the sheet for issue to the public. Owing to the comprehensive nature of this programme the limitations of space confine us to the baldest possible statement of facts, and each of the sections that follow is capable of expansion into a considerable booklet. It is probable that individual readers may be familiar with the matter contained in one or more of the sections, but for the benefit of others it was thought advisable to touch on all relevant facts. It is particularly regretted that the historical side of the subject has had to be passed over in silence. Some solid foundations have been laid for this study*, but there is a great deal of most interesting and valuable research work awaiting to be done.

In the course of writing this article, the author has received useful suggestions and criticisms from several of his colleagues; these he here gratefully acknowledges.

I.—The Hydrographic Department.

The Hydrographic Office of the Admiralty was instituted in 1795 for the production of navigational charts, but of its early history and of the greatness and unfortunate end of its first Hydrographer, Alexander Dalrymple, F.R.S., nothing can be said here. In addition to fulfilling this purpose, the Department now contains technical branches dealing with such matters as Sailing Directions, Tides, Lights Lists, Notices to Mariners, etc., staffed by naval officers, as well as a clerical staff and a section for the issue of the Department's publications. Here, however, attention will be confined to the

* *Memoirs of Hydrography*, by Commander L. S. Dawson, R.N. 2 vols. 4to. H. W. Keay, Eastbourne, 1885.

largest and oldest section, the Chart Branch; and of that we shall be able to deal only with that side of its activities directly concerned with the production of navigational charts for public use.

The whole Department is under the control of the Hydrographer of the Navy who is a naval officer, usually of flag rank, and, of course, a hydrographic surveyor; he is seconded by an Assistant Hydrographer, also appointed from the senior ranks of the Surveying Service, while the Chart Branch is directed by a Superintendent of Charts, a surveying officer of commander's or captain's rank. That part of the Chart Branch concerned with the production of charts is divided, for geographical purposes, into sections which operate under Chief Cartographers, who are promoted from the cartographers' ranks, and from them is appointed the Superintending Cartographer who holds the position of Assistant Superintendent of Charts. Draughtsmen are recruited by open competitive examinations in which, amongst other subjects, a fair proficiency in English and Mathematics is looked for, in addition to Drawing and Plotting; the draughtsmen work under the direction of the cartographers, who are also appointed as the result of open competitive examinations, among the subjects of which may be mentioned a Modern Language, Map and Chart Projection and Hydrographical Plan Drawing, special stress being laid on Mathematics including Spherical Trigonometry. The general standard expected is approximately that of a pass University degree and several members of the staff are, in fact, graduates.

Attached to the Chart Branch are several Naval Assistants, experienced surveying and navigating officers, whose duty it is to study the daily flow of hydrographic information which comes through correspondence, foreign Notices and similar channels, and to deal with these, more particularly with reference to matters of such navigational urgency as to require announcement by Notice to Mariners and the immediate correction of the chart plates.

II.—Types of Charts.

The Hydrographic Department produces for sale charts for various purposes, but the great majority is naturally included in the first of the following categories:—

1. Navigational Charts.
2. Ocean Charts for Great Circle Sailing: Track Charts.
3. Meteorological Charts: Ice Charts.
4. Telegraph and W/T Station Charts: Magnetic Variation Charts: Oceanic Sounding Charts.
5. Various diagrammatic sheets: Index Charts.

There are now nearly 4000 charts issued for public use.

III.—Sources of Data.

The Chart Branch possesses a well indexed repository containing over 200,000 original documents, to which several hundreds are added annually. Some of the older of these documents date back to the middle of the seventeenth century and amongst them are many fine specimens drawn on skins. Space forbids even a mention of the most interesting and valuable records that are here preserved, but their nature may be judged from the fact that they include the splendid drawing on vellum of Dampier's voyage to the East Indies and the original drawings for Greenvile Collins' *Great Britain's Coasting Pilot* (published 1693) which is stated in the preface to contain the first English printed charts, those used previously having been Dutch.

The original documents of modern times are derived from various sources of which the following are the most important. (*a*) The Surveying Service of H.M. Navy. This section of the Navy includes eight vessels specially equipped for surveying work, staffed by specialist officers, and their work is carried out in the British Isles and other parts of the Empire. A survey embraces an exact triangulation, astronomical observations, topographical work, tidal records over an extended period, the compilation of sailing directions, selecting and drawing views most likely to be useful, and taking soundings and making "sweeps." The soundings are taken with extraordinary thoroughness and on the "fair sheet," soundings which have been taken, and selected, from the collector tracings (made from the crowded plotting-boards of the boats) are still shewn in a thickness of nearly 200 to a square inch in the shoaler waters and with great detail elsewhere. All doubtful patches are examined for possible dangers with elaborate care; the quality of bottoms has always to be noted.

We believe that it is not insular prejudice, but a plain statement of fact, to say that the work done by the modern Surveying Branch of H.M. Navy represents the highest level yet reached in the science of Hydrography; and the professional nature of the personnel insures that this science is adapted to practical ends.

(*b*) Colonial Surveying Services. Certain of our Colonies such as Australia and South Africa now maintain Surveying Services which carry out work on lines similar to those of the Royal Navy. Canada has, in addition, her own Hydrographic Office and produces charts of her own waters. A special pride of place must be accorded to the Marine Survey of India, a service with a history and tradition dating from the days of the great Company.

(*c*) Harbour boards and similar corporations. The Depart-

ment is generously served by the local authorities of harbours, rivers, docks, etc., of Great Britain and all parts of the Empire, with detailed surveys and examinations of their own localities. The cable companies also give valuable information about the deep waters of the oceans.

(*d*) Ships of H.M. Navy. Apart from the rigid and precise work mentioned above, all navigating officers of H.M. ships have to note anything likely to be of hydrographic interest and to forward this to the Department. Frequently valuable sketch surveys are added.

(*e*) Other Sources. Officers of the Mercantile Marine often avail themselves of the official invitation to send hydrographic information to the Department, and this source is particularly valuable since it frequently brings in material from parts of the world of which the charts are based on old or imperfect surveys. The various semi-official expeditions to little known parts also provide sketch surveys and details that are of the greatest use.

(*f*) Foreign Governments. The middle of the nineteenth century saw the beginning of a great expansion of hydrography amongst nearly all nations, following the lead of one or two European powers who had borne the brunt of charting the coasts of the known world. For many years past there has been a fine spirit of internationalism in the free exchange between all Hydrographic Offices of their new charts and new editions of charts. For information about foreign waters we are now, of course, dependent upon the surveys done by those countries. This exchange has now greatly broadened its scope, thanks to the post-war institution of the International Hydrographic Bureau, and on innumerable matters concerning the design and production of charts, the experience of all nations is made mutually available. With the assistance of periodic conferences, considerable steps have been made to secure uniformity of symbols and arrangements on the charts of different nationalities. The fine work being quietly done for navigators by this body is all too little known to the general public; we may perhaps recall with pride that its first President was a retired Hydrographer to the Navy, the late Sir John Franklin Parry.

IV.—Projections.

Navigators will be so familiar with the respective properties of the Mercator and Gnomonic projections that it may seem superfluous to describe them here, but for the sake of other readers a brief account of their natures and purposes must be included.

The Earth is a sphere (almost) and its surface is therefore curved; a chart or map must be drawn upon a flat plane. It

is obvious that the one cannot be represented exactly upon the other and the question of how best to accommodate the difference has exercised the minds of mathematicians since the days of the revival of learning. It is possible to produce a map that will be exactly true to the sphere in one property to which all others must be sacrificed, often with grotesque results in appearance. The seaman is fortunately spared the more abstruse problems of the theorist and the topographer; he is concerned with two things only—distances and bearings. Since he navigates by the North, whether with a magnetic or a gyrostatic compass, he must have a chart so constituted that, if he lays off a straight line on a certain bearing to the North at one point, all other parts of that line will have the same bearing relative to that North; such a line is known as a "rhumb line." On the sphere all lines running due North and South must obviously converge on the Poles, yet a chart to show a rhumb line must be so constructed that these lines will be parallel to each other.

This problem was solved in the early days of scientific navigation and most charts to-day are still constructed on the projection that bears the name of its inventor, the Dutch mathematician Gerard Mercator (1580). While keeping the meridians of longitude parallel on his chart, he gradually increased the distances between the parallels of latitude so that the true ratio of the latitude to the longitude was preserved throughout. Thus the scale of the chart increases, as it recedes from the Equator, until it becomes infinity at the Poles, and for this reason Mercator charts cannot be constructed for very high latitudes.

All circles which bound the maximum circumference of the globe, or, in other words, have their centres at the centre of the Earth, are called Great Circles; they have in common the property that the distance measured along the Great Circle, passing through any two points, is the shortest possible distance between those points. All meridians are Great Circles, but the Equator is the only parallel of latitude that fulfils the conditions; since the meridians converge on the Poles, no Great Circle, unless it be one of them or the Equator, can be a line of constant true bearing. Conversely, no rhumb line, with the exceptions mentioned, can represent the shortest distance between two points. If a flat surface be laid to touch the sphere at a given point, all Great Circles projected on to it from the centre of the sphere will appear as straight lines and a chart constructed on this principle is called a Gnomonic chart.

For Admiralty charts drawn on a mid-latitude natural scale of $\frac{1}{50,000}$ or smaller, the Mercator projection is used; plans and approach sheets on larger scales are drawn on the

Gnomonic projection. Ocean sheets for Great Circle sailing are also constructed on small scales, but on these the details of water work are omitted as they are intended for plotting Great Circle tracks to be transferred to Mercator charts. Polar Charts are, of course, always on the Gnomonic projection.

The construction of a Mercator projection is carried out by the aid of meridional parts on scales up to 1 inch to a sea mile at mid-latitude, but above that scale the Tables giving the actual length in feet of a minute of latitude and longitude for every ten minutes of the quadrant are used. These Spheroidal Tables are also used for constructing Gnomonic graduations on large scales, while smaller scales on this projection may be constructed either by direct calculation, by the ingenious adaptation of Towson's Tables for Great Circle Sailing, or from the Tables of Co-ordinates. Space compels us to pass over, in this hasty fashion, what is an important part of the work of the staff of the Chart Branch. Fortunately all their materials and methods have been placed at the disposal of the public in a series of booklets obtainable, at the chart agents, for very small sums and in the undermentioned works the reader will find full details of the Admiralty practice in constructing the projections for its charts.

1. *A Table of Meridional Parts for the Terrestrial Spheroid*, by J. W. Atherton (of the Hydrographic Department). J. D. Potter, 1910. Price 9d.

2. *Spheroidal Tables*, by Robert Carrington (late of the Hydrographic Department). (J. D. Potter, 1913. Price 9d.)

3. *Tables to Facilitate the Practice of Great Circle Sailing . . . and their Application to the Construction of Gnomonic Charts*, by John Thomas Towson and J. W. Atherton. (J. D. Potter, 1912. Price 1s.)

4. *A Table for the Graduation of Charts and Surveys on the Gnomonic Projection.* Prepared in the Chart Branch of the Hydrographic Department. (J. D. Potter, 1912. Price 6d.)

5. *The Admiralty Manual of Navigation*, 1915 Edition. Chapters III. and V. 1922 Edition. Vol. 1., Part II., Chapters III, IV. Part III. Chapter I. (the more mathematical part is now given in Vol. II.)

V.—Geodetic Positions.

The exact position by latitude and longitude of a point upon the Earth's surface is a very serious matter; the sort of position that is good enough for a library atlas is of no use for a plan that may be constructed on any scale up to 18 inches to a mile. For chart work the most precise astronomical fixing to a small fraction of a second is essential. The determining of latitudes has not presented great difficulties, being merely a matter of accuracy and condition in altitude observations; but the case of longitudes is different. These are purely relative to some arbitrary meridian of origin, hence their determination depends upon some method of finding the angular distance of the desired meridian from that origin. Up to comparatively recent times the ship's chronometers were the best means available, and although remarkably accurate results were obtained the introduction

of telegraphic signals enabled closer determinations to be made, while the still more recent use of wireless telegraphy, across vast distances, has led to the revision of many established longitudes.

Observations for positions are obtained from a number of sets of readings by different observers. The evaluation of the final result is by no means a simple matter of "striking an average"; the relative merits of the individuals have to be ascertained from their respective readings, and the value of the readings in the sets of those observers finally selected has to be judged. These matters are investigated in accordance with mathematical laws from the complete records and the process is too elaborate to be explained here. The method devised in the Hydrographic Department has been recently published and should be consulted by all who may have occasion to take such observations.*

Coupled with the elaborate observations necessary for fixing a key position there must be considered the longitudes of what may be called secondary stations: that is to say, determinations which depend, either by triangulation or by angular measurement, on one of the previously fixed positions. This process may be repeated until many interdependent positions are interposed between a longitude and the original basic meridian. A disturbance of any part of the chain may have far reaching effects on other parts which will in turn affect the whole plotting of the surrounding work. But it may happen that there are two well defined positions on a chart, one of which becomes upset, while the other, not being affected by that chain, is unmoved; what is to be done with the chart between these points and is it certain that the second position is correct as it stands ?

Such a problem and a hundred kindred matters are dealt with by a special section of the Chart Branch wherein all questions of geodetic positions, their accepted values and relative effects, are worked out. This section has an extensive library of printed material, from all over the world, of important observations and data, in addition to records of all surveyors' observations and similar manuscript material. The highly complex nature of this work calls for a clear, analytic mind coupled with mathematical abilities of an advanced order.

A reference may here be made to the booklet of tables with a preface describing the interesting manner in which calculations between two known stations have been simplified, with the reverse operation where one station is fixed and the

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* *Notes on the Determination of the Value accepted from Observations for Latitude and Longitude*, by T. J. Richmond, B.Sc., Cartographer, Hydrographic Department, Admiralty. (J. D. Potter. 1927. Price 1s. 9d.)

position of the second found by the bearing and distance to it, from the first.*

VI.—Use of Data.

All new original documents coming into the department are discussed each week by the Superintendent of Charts in consultation with the Chief Cartographers. New charts or corrections to existing charts are then decided upon for submission for the approval of the Hydrographer. In addition, schemes for new charts, plans, series of charts, or re-arrangement of sheets of plans based on information already in the office, are discussed. Suggestions for new charts and amendments to existing charts are frequently received from outside sources and always receive the most careful consideration; for, next to the requirements of H.M. Navy, the assistance of navigation generally is the principal object of the Department.

All originals arriving in the Department, whether they are surveys or Foreign Government charts, are first of all carefully inspected for possible new dangers whose early announcement by Notices to Mariners can be made, while the original is being used with greater thoroughness for chart production and correction.

We will suppose that a new chart is to be produced from some surveys recently made by one of the surveying vessels. It is not often that the cartographer has a perfectly straightforward task, for there is usually some portion of the projected sheet to be made up from other work but a simple case will illustrate some of the aspects of office practice. There may be two or three fair sheets from the surveyor covering the area and when the scale of the new chart and its limits have been fixed, it is necessary first of all to calculate, from the triangulation data, the relative astronomical positions of the main stations of the survey and so to connect up the whole of the work. In cases where the surveys are of different dates, this work may involve considerable balancing and adjustments, for it is not always possible for successive surveyors to use the same marks. Sometimes the stations have to be taken on rocks that dry only at low water, or other circumstances may obliterate the positions. Again, the surveyor's work is often carried out under conditions of great climatic difficulty, or the hostility of natives may prevent proper shore work; where the work is chiefly at sea and only floating beacons or ships' positions are available, discrepancies may arise. In preparing a sheet from a new complete survey where there are plenty of sound positions, the surveyor's fair sheet is a model of accuracy, but in other cases the respon-

* *Tables for Determining Geodetic Positions . . . together with Methods of Using Co-ordinates*, by John W. Atherton. (J. D. Potter, 1912. Price 6d.)

sibility of the cartographer may be considerable and he may have to search through masses of observations to find the most satisfactory method of reconciling the data.

The Geodetic Positions Branch is then consulted for the latest accepted positions in the neighbourhood to ensure that the positions used for the new sheet will be in agreement. This point may again involve difficulties, with the increasing accuracy of our knowledge of longitudes in more remote parts. The positions then fixed, the skeleton graduation is plotted on a sheet of stout Whatman drawing paper and the outer borders completed in accordance with the standard patterns. Nothing else appears on this paper. Charts are now always drawn with the true North parallel to the East and West borders, though in the case of Gnomonic charts this applies only to the central meridian.

The work from the original documents can then be used in a variety of ways, depending largely on the difference in scale between it and the chart to be produced. An increasing use has been made for many years past of photographic reduction, the work being printed direct from the glass negative to a lithographic zinc plate from which the paper proofs are pulled; as there is no damping in any part of this process, the printed paper gives the exact size of the original glass negative. If the reduction is not great, all the work on the original will be legible in the photograph, but in other cases a tracing is made from the original of the work required and this is photographed instead. Another method also largely used is that of reducing an original by similar squares. Fine pencil lines are ruled on the document at right angles, either through the graduation or else by scale, and the paper upon which the work is to be reduced is "squared-up" with exactly similar squares, either from the graduation already plotted or on the correspondingly smaller scale. It is a rigid rule that the smaller of such squares should never exceed one-tenth of an inch. Such a method must always be used when some adjustment has to be made between points on the original or when a drawing on one projection is being converted into another projection.

The main part of the work of a new sheet, or large correction, is nearly always drawn upon tracing paper which has several advantages in addition to the obvious one of its transparency. It is not so liable to shrinkage owing to change in atmosphere as ordinary paper, and it offers a smoother surface for the draughtsman's pen; there is also a possible convenience for the engraver as will be seen in due course. The coast line with the topography, properly selected, is drawn in black ink, but for the sake of clearness, hill contours, trees and other such like features are drawn in coloured inks; similarly, rocks which dry at low water are distinguished from islands

and coast, by being drawn in a colour, usually blue. One of the most important parts of this work is the selection of the soundings from the crowded original; this may have already been done when a tracing from the fair sheet is prepared for photography, but otherwise it has to be done as the work progresses. The utmost care has to be taken in order that, while the exact trend of the bottom is indicated, all shoals and their approaches are shewn; it is not sufficient only to show the shoalest soundings, for in some conditions the soundings may give a useful hint as to the seaman's whereabouts so that an indication of the deeper water must be given as well, while the nature of the bottom is also a guide. In many cases this process of a selection that will be at once sufficient and not too crowded is a matter of great difficulty to the cartographer and his assistants. The fathom lines are carefully followed from the original, upon which they are traced in pencil, if not already shewn thereon; the one, three, six and ten fathom lines are now considered the most important, the two and the five fathom lines being also inserted as required. On the tracing these are indicated by coloured lines which the engraver translates into the correct symbols in accordance with long established practice. The increased draught of modern vessels has led to the recent preference for the six fathom line and older charts are being brought into line as opportunity offers. The units in which the soundings are shewn depend upon the scale of the chart and also upon the nature of the information supplied; on large scale plans and approach sheets, feet are used, while for smaller scales it is now the custom to give soundings in fathoms and feet, instead of fathoms and fractions as in former years. Whatever the units may be, in which the surveyor's information is given, they are never converted to give an appearance of greater precision than is warranted; thus, *data in feet may be given on the chart as fathoms and feet, but data in fathoms would never be converted into feet.*

The arrangement of the writing on the chart is given careful attention; a uniformity of appearance must be preserved and writing that is curved must approach the object in a particular manner; important sea work must not be obscured and relative importance must be indicated by the nature of the lettering used. Every effort is made to utilise different styles to render useful facts obvious at a glance; thus, all under-water dangers, shoals, sunken rocks, etc., have their names in what is known as Egyptian type in which the letters are of equal thickness throughout and are plain with no "serefs" (the fine horizontal strokes at the top and bottom of the letters in the other types used); names on the water in capital letters are always sloping, to distinguish them from topographical names in capitals; descriptions of lights on

buoys are in sloping letters, while those of lighthouses are in upright letters; and numerous other instances could be mentioned. For conspicuous objects a special type, known as "Clarendon," is reserved.

For some years past a policy has been observed of ridding the chart of much superfluous matter whose proper place is in the appropriate volume of Sailing Directions. This has lately been carried a step further by abolishing the lines of descriptions of symbols that used to be given in the title, a simple reference to the sheet of explanations being inserted in their stead. Views are drawn from the originals in a manner suitable for the engraver. Bearings and leading lines are checked and drawn in; and compass roses and the table of tidal information inserted, of which more will be said later. All other details such as lights, buoys, beacons and notes are then added.

At this stage the drawing is given a thorough revision from the originals and it has then to be gone over with the published Sailing Directions and any new information sent in by the surveyor. Existing charts covering the same area are compared with it to see if any important discrepancies have to be enquired into and all recent Notices to Mariners likely to affect the chart are examined. The Lights List with its latest amendments is consulted, and finally the whole drawing is looked over by the Chief Cartographer in charge of the section concerned. The projection with the tracing, or tracings, is then sent to the engravers, from whom in due course they return, accompanied by an ordinary proof, one pulled on tracing paper and another that has been pulled "dry." The object of the latter is that measurements may be checked, the ordinary proof being damped and so liable to shrinkage.

The work of the engraver is now carefully revised and all the measurements of the graduation are checked, accuracy to one-hundredth of an inch being insisted upon. Then the laying down of the work is checked by means of the tracing paper impression. These fundamental points being settled, the wet proof is divided up into squares and the work examined minutely, mistakes, omissions and uncompleted letters or figures being marked in red ink. At this stage of the chart the tint has not been inserted, for it is difficult to make alterations over the tint without the "patch" shewing; neither are the views engraved nor the building hatched, and the low water rocks are left in outline only. Before sending the corrected proof back to the engraver, care is taken that any work or information that has come into the office since the drawing was made is incorporated.

Unless the corrections be unusually heavy the next stage will see the completion of all details except the tint and the

meridian and parallels, although the latter may have already been ruled faintly on the plate. After another revision the proofs are sent back for final corrections and the completion of all outstanding details. The chart is now ready for publication but before it can be issued a further process is gone through. It is first of all given a revision from the originals from which it was compiled and a final search made for any recent information. It then has a label fixed on the back by which it circulates to all other branches of the office for checking by the Sailing Directions, the Tidal Branch, the Lights List and Wrecks Officers and other branches. After examination by the chief officers of the Chart Branch, it goes to the Assistant Hydrographer and finally, when the amendments have been carried out, to the Hydrographer for his signature. The chart is then ready for printing for issue to the public, a fact which is announced by a Notice to Mariners.

When a new sheet is issued or a new plan inserted on a chart, every care is taken that the correct reference shall be given on the next smaller scale and that any necessary references shall appear on the new chart; also that these new productions are properly shewn on the index charts and in the catalogue.

The service of these original documents is not yet ended, for all smaller scale charts which include this area must be corrected for this new work and herein we touch one of the main duties and difficulties of the cartographer. Much of his time is spent in putting new wine into old bottles, for surveyor's work is not always used for a new chart; it may mean only the extensive correction of existing sheets with, possibly, the production of new plans inset on them. It is this fitting together of new and old work that forms a fruitful source of difficulty whether it be in patching up a chart or in producing a new sheet from a mixture of new and old originals. If bearings are preserved, apparently similar points will not coincide; or else scales do not seem to correspond; or positions affecting the laying down of neighbouring work may appear to require alterations. These and many similar problems have to be faced and a solution found. Groups of islands, of which the individual members lie too far apart to be connected up by direct observation, and of which our knowledge is scanty, are sometimes found to be not in correct relation and an alteration at one end of a chain may affect work depending on the position of the islands at the other end. In this work of correcting smaller scales, the matter of elimination of the material shewn in the more detailed chart calls for much experience and judgment.

Although this description gives but a partial idea of the work of the Chart Branch, it must suffice in the limits of this article to shew that every possible care is taken that the

published chart shall be as accurate as the available information permits. Should it be necessary to complete some portion of a sheet by enlarging an original document, this fact is invariably shewn by engraving all the work in this part of the chart in fine line, known technically as "hair-line."

VII.—Compass Roses.

Charts shewing the magnetic variation and the rate of annual change are published every five years, the information being supplied to the Department in the form of curves constructed by the Astronomer-Royal from accumulated observations all over the world. Compass roses, with circles shewing the True bearing, and the Magnetic in both degrees and "points," are placed on the chart on the variation as given for the current year. The placing of these compass roses is a matter requiring some care, for they must obscure as little important work as possible and must also be placed so that they are not touched by the fold of the chart. The statement of the variation on a compass is always placed on the side to which the needle is inclining and the annual change on the other side.

Bearings on leading lines or on views were originally given in "points of the compass," thus N.W. $\frac{3}{4}$ W.; these were changed many years ago to bearings in degrees, numbered by the quadrant, thus N. 54° W. Both these methods referred the bearing, of course, to the Magnetic North, but the introduction of the gyro compass led to the statement of bearings being made in degrees, both True (from 0° through East to 360°) and Magnetic (as before), thus: 298° (N. 54° W. Mag.) Still later, the Magnetic bearings were entirely dropped and the True bearing only is now given, thus, 298°.

VIII.—Tides.

All tidal observations, of establishment, of rise and fall and of tidal streams, go to the Tidal Branch for computation and reduction. This branch is under the superintendence of a naval officer who has specialised in this subject and from it are issued the Admiralty volumes of Tide Tables. All information of tidal nature and about datums has to be submitted to this branch for confirmation before being placed on charts.

In conformity with those of other nations, British charts no longer shew tides scattered over the sheet, but in a formal table placed as near the title of the chart as is convenient. Similarly, the tidal streams are collected in a table, the old "rose" of arrows being abandoned. For further information upon this subject the reader should consult the valuable introductions to the *Admiralty Tide Tables*, Parts I. and II.

In connexion with the table of tides shewn on charts one small point may be mentioned as indicating the attitude of the Department towards the users of its charts: the hours of all establishments are shewn in Roman numerals with the exception of "2" which is always given in its Arabic form, lest the Roman "II" should be taken for eleven.

IX.—Orthography.

As far as possible all names are now given on charts as they would be spelt in the country of their origin. Where a marked change is made, the older form is shewn in "hair-line" in brackets under the accepted form. This is a matter in which the Sailing Direction Branch has a deciding voice. It should be borne in mind that in some countries the spelling, pronounced on English lines, gives quite a false impression of the actual sound of the words and the information given in the Sailing Directions upon this point should always be consulted. One need go no further than the Gaelic names on the West Coast of Scotland for an illustration of this feature.

The orthography of the Royal Geographical Society's "Permanent Committee on Geographical Names" is being accepted, for the Admiralty charts, as its work progresses.

X.—Reproduction.

All stages of the work of actual reproduction of the Admiralty charts are now carried out by a branch of H.M. Stationery Office in a special building, which also houses the Admiralty Chart Establishment, the clerical section of the Department concerned with the issue of hydrographic publications. A cartographer, who is assisted by a staff of draughtsmen, acts as a liaison officer between the Department and the Stationery Office.

Methods of reproduction of charts vary greatly in different countries, depending largely on the nature of their productions. For British Admiralty charts of a permanent nature, no satisfactory substitute has been found for the age-long method of engraving the work upon a copper plate; this is still the basis of practically all our charts, though they are no longer, in the main, printed from these plates.

In preparing a new plate the borders and graduation are first marked out and the main lines cut. The work is then laid down on the highly polished surface in one or two ways, the plate is coated with a thin film of wax and if the tracing sent is small and the work clear and open, it is laid face downward on the wax surface, fitting exactly by the marks given, and the work marked through on to the wax with a fine pointed style. The most usual method is for the engraver to make a tracing or a series of tracings of the work with a style on a sheet of glass-like gelatine. Into these cuts he

rubs a red powder which is transferred to the wax when the gelatine is laid face downward on it. Through these marks on the wax the work is scratched on to the copper with a needlepoint and the wax then polished off. With the original in front of him, the engraver proceeds to the actual cutting of the work which, it will be understood, all appears on the copper backwards. When the difficulties of this work are realised and the neatness and the uniformity of the result considered, it will not be wondered at that an apprenticeship of seven years is required for a professional engraver.

If a correction to a copper plate already engraved has to be made, the copper is beaten up from the back in the area concerned and then scraped and re-surfaced on the front; damaged work around the correction has to be reinstated and the new work engraved in the clear space obtained. When a copper plate has to be printed from, its face is protected by an electrolytic deposit of steel, as otherwise the softness of the metal would allow it to be worn by repeated contact with the paper, resulting in the work becoming shallow and finally failing to print. Some of the copper plates in daily use are nearly a century old and a few date back even farther. The copper has to be specially prepared by hammering to an optimum of hardness and the surfacing is carried out so that no scratches or pit marks are left. The copper plate for an ordinary "double elephant" chart (about 42" × 28") weighs roughly 40 lbs. Engravers tell us that copper is not what it was in the old days; but very possibly John Norden and Speed heard the same complaint in the early seventeenth century.

A much corrected copper plate may eventually crack in the thin portion. This can be treated in several ways; when a plate, in otherwise good condition, shews signs of becoming too thin in one place it can be brought up to the original thickness by an electrolytic deposit of copper on the back and so saved. But if it should have actually cracked, the patch so affected is cut clean out of the plate and the hole filled up by gradually depositing copper, the rest of the plate being protected with wax and a piece of surfaced plate being temporarily placed over the hole for the copper to form smoothly against. Sometimes, however, a plate will be badly buckled as a result of its thin patch or from other causes; there is then no remedy but to make a duplicate of the plate, for if the hole were patched the spring of the buckled plate in the printing press would cause the new copper to come away from the old.

Duplicate plates are of two kinds. The first method is to place the old plate in an electrolytic bath and to grow on to it a matrix plate. When completed this is an exact duplicate of the original plate, save that it is reversed, all the work

being raised instead of hollow, and reading, of course, from left to right. This matrix is then placed in the bath, the cracked areas being scraped smooth, and a second plate grown by electrolytic deposit, which, being again reversed, gives an exact duplicate of the original. The work in the cracked area is then engraved on the part left and after a revision for any small defects the plate is ready for use.

The second method of preparing a duplicate plate is to etch the work with acid. The surface of a copper plate is coated with a special preparation of bitumen which has the peculiar property that when it is acted on by light it becomes a hard surface impervious to the acid. An impression from the old copper plate is printed down on to this sensitised surface which is then exposed to diffused sunlight; after a few days, all parts of the bitumen (known as "the resist") not protected by the black ink of the impression are hardened and the rest, remaining soluble, can be washed off. Thus an exact print of the original plate is left exposed to the acid. The plate is then put over a bath, face downwards, and the acid is sprayed on to it from a large number of fine jets; a few moments suffice for the plate to be bitten to the required depth and after washing and treating to remove the "resist" an impression can be printed from the plate. The engraver can then improve any small defects and after revision the plate is available for use. Plates made by this method are known colloquially as "process plates," and it has one advantage over the electro plate that it can be made on a properly hardened copper, whereas the deposited copper is softer. On the other hand, the nature of the process tends to cause a slight thickening of the work so that it is not suitable for very fine or crowded detail.

A great deal of work of a temporary or quasi-permanent nature is now reproduced by lithographic methods. This process, accidentally discovered by the Bavarian, Senefelder, towards the end of the eighteenth century, is based upon the antipathy between grease and water. The drawing is made on a special type of stone or upon the finely granulated surface of a zinc plate; the surface is kept perfectly clean of all grease or dirt and the ink used is made of greasy substances, combined with lamp black to enable it to be seen. When the plate is put in the printing press it is damped, and the moisture is held in the granulations: the ink from the rollers will then only adhere to the greasy portions and an impression can be taken from it. As with the copper-plate engraving, all work must appear reversed on the lithographic surface and the proper performance of this work calls for great skill that is only to be acquired after a long apprenticeship.

An increasing use is now being made of a combination of copper engraving and lithographic drawing for charts subject

to the continual change in one portion, such as harbours and river entrances. The outline and topography and, possibly, more stable portions of the water-work, are engraved on the copper, the rest of the plate being blank. This can be transferred to a lithographic surface by means of an impression pulled with greasy ink on a plaster surfaced paper. When this work is on the stone surface, the rest of the water-work is drawn in thereon, thus saving the continual correction of the copper plate. Should a new edition of this sheet be required the process is gone through again and a new stone prepared.

Lithographic surfaces give excellent results for a time, but will not stand numerous printings, the work getting thicker; also the nature of the method makes the work more liable to damage and it cannot be repeatedly corrected without a tendency of the grease to spread.

XI.—Printing.

Although charts used to be printed almost entirely from the copper plate, the method has several disadvantages, the worst being that, in order to allow the paper to absorb the ink properly from the cuts, it has to be damped and thus the resulting print shrinks considerably on drying. Also the continual use of the copper plates leads to wearing of the surface in spite of its protection of steel and to a buckling of plates worn thin with many corrections. For these, and other reasons of economy, charts are now chiefly printed by lithography, an impression of the copper plate being taken in special ink as described above and laid down in a zinc surface. This zinc plate is then placed in a flat bed direct printing machine and, once it is "made ready," copies can be run off with great rapidity. As the only damping occurs in laying the transfer to the zinc, when it is under pressure, little or no distortion by shrinkage occurs. The drawback to this method is that the time taken to "make ready" on the machine makes it extravagant to print only a few copies this way, whereas on the hand-operated, copper plate press one proof is pulled at a time. Thus for a few copies of a large number of different plates, copper plate printing is quicker and more economical, but for a large number of copies of a few charts the lithographic machine is enormously more efficient.

When colours are introduced into printing, the lithographic method is essential, as the shrinkage on a copper plate proof would effectively prevent any possibility of the colours fitting the desired outline. A separate zinc plate is made for each colour, the black work being shewn upon it in an indelible ink which does not print; the adjusting to get exact "register" in printing these colours may take some time and this, with

the extra printings involved, adds greatly to the expense of producing charts of this nature.

The sections of charts in red and black that are appended to many Notices to Mariners are printed from lithographic stones, the work being transferred from the original plate. These are known colloquially as "blocks" from the fact that many years ago they were printed with the letterpress from actual photo-zinco blocks.

When the original of a chart is a lithograph, either a zinc plate or a stone, this is never used for printing purposes, but a transfer is made to a second zinc in order to preserve the original in good condition. If a copper plate is under correction so that it cannot be used for printing, a transfer to zinc is made unless there is already a printing lithographic plate in use. When the correction is completed and the new edition ready for issue, this zinc is put aside to be cleaned and used again, and a fresh transfer is made.

The nature of the plate used for printing any chart may now be found in the letters just inside the extreme south-east corner of the sheet; in cases where the plate is a transfer from some original, the year date in which that transfer was made is given. The following list will assist identification, the capital letter indicating the actual plate used, and the small letters the original, if that is not being printed from.

C = Copper
P = "Process"
E = Electrotype
Z = Zinc
S = Stone
} originals.

Z C, S C — An original stone or zinc, a portion of the work on which has been transferred from an incomplete copper plate.

Zc. Zp. Ze., Sc. Sp. Se. — Printing plates or stones made from complete original copper plates.

Zs. Zz., Ss. Sz. — Printing plates or stones made from complete original lithographic plates or stones.

Zsc. Zzc., Ssc. Szc. — Printing plates or stones made from composite lithographic originals.

Certain other signs on the chart may be here explained as their meaning is not obvious at sight. Near the number of the chart, in the south-east corner, will be found figures in brackets, as for example (34.23×28.15). This shews the exact dimensions of the chart in inches, measured on the copper plate, along the innermost of all the lines of the graduation. These figures will be found of assistance if it is desired to ascertain what shrinkage has taken place in printing. Just outside the north border, at the eastern end of the sheet, will be found two numbers, as thus:—62.27, indicating that the printing of this copy was done on the sixty second day (or 3rd of March) of the year 1927.

XII.—Current Corrections to Charts.

Important matters affecting navigation are notified to seamen daily by the issue of the Admiralty Notices to Mariners, and it is a rule that every chart issued to the public must be corrected so as to bear the number of the latest notice affecting it. The chart plates are corrected daily for all Notices to Mariners, the lithographic printing plate, if there be one, being done first and the copper original after; for the correction of the stock copies already printed, a staff of draughtsmen is employed both at the Admiralty Chart Establishment and on the chart agent's premises. In addition to Notice to Mariners corrections, chart plates are amended for many things that do not affect navigation; if these are small, the operation is recorded on the chart plate by a date enclosed in a rectangle in the line of "small corrections" outside the western end of the south border. For such a correction no existing copies are cancelled, nor are any stock copies corrected.

When an extensive correction of an important nature is made to a chart, a "new edition" is issued which automatically cancels all existing copies of the chart; for a new edition the whole chart is overhauled and brought thoroughly up to date. Recently, a restricted form of new edition has been introduced (or revived) by which an important correction is made and all copies cancelled, but the chart is not corrected beyond the immediate area affected: this is known as a "large correction."

When a fairly large amendment is made that is not of navigational importance and not consequent on a Notice to Mariners, but by which it is thought advisable to cancel existing copies in stock, a minor form of cancellation takes place, which is indicated in the line of "small corrections" by a date enclosed in brackets. New compasses on a sheet may be quoted as an example of this.

The Hydrographic Department has before it one all important object in the production of its charts—accuracy. All calculations must be carried out to give a final result correct to the nearest hundredth of an inch, and the same limit is set to all plotting, drawing, engraving and lithography. To its efforts to keep its chart plates constantly up to date may perhaps be attributed the doubtful claim that the charts of one or two other countries excel ours in beauty of appearance; none can claim a pre-eminence in utility.

In spite of the comparatively low price of charts, it is perhaps useful to remind the public that this section of the Government service is self-supporting, the proceeds from sales having for some years past approximately balanced all the civilian costs. And it renders a service to the public that by its very nature could not be given efficiently through

any private channels. If those who make useful suggestions for charts do not always see their proposals carried out post haste, we would ask them to remember the enormous extent of the world's seaboard and the increasing flow of material from all sources; and to believe that every effort is being made to cope with it by a staff necessarily limited in these days of public economy. Nor has the Department yet recovered from the effects of the Great War, when its energies, for longer than that unhappy period, were concentrated on other sides of its work and a considerable proportion of its staff withdrawn to another Service. For the majority of these this withdrawal was temporary, but for some, alas! it proved permanent.

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